Bulletin No. 254

Diseases of Potatoes in Idaho

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Agricultural Experiment Station
March 1944

Published by the University of Idaho, Moscow, Idaho

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Introduction

POTATO growers in Idaho are extremely fortunate from the standpoint of the disease problem involved in production. This is true for several reasons. Although there are many important potato diseases present in Idaho, varying in their severity from year to year, there are others with which the Idaho grower does not have to contend. Among the latter are such diseases as late blight, powdery scab, and black wart. These three diseases are caused by fungi and, in some out-of-state potato-growing sections, are very important. Expensive control measures must be provided for annually to combat these diseases, thus adding materially to cost of production. Since these three troubles do not occur in Idaho, the Idaho growers' cost of production is reduced accordingly. There are still other diseases of lesser importance, occurring in other potato-growing sections, from which Idaho is free.

On the other hand, the diseases of importance which do occur in Idaho likewise occur in the other potato-growing sections. Thus, it should be recognized by the growers of Idaho that they are very favorably situated from the standpoint of the disease problem in potato production.

Not to be misled by the above statements, every potato grower in the state should realize that there is a disease problem in production, and unless this problem is recognized, chances for successful production will be lessened.

The diseases which occur in Idaho can be divided into three groups based on cause: (1) those produced by viruses; (2) those of a parasitic nature caused by bacteria and fungi; and (3) those produced by adverse environmental conditions.

Virus Diseases

The exact nature of the causes of these diseases is not known. However, evidence indicates that they are caused by the so-called filterable viruses. A filterable virus capable of producing a plant disease is a microscopically invisible agent in the juices of the plant which has the ability to pass through filters that remove all ordinary bacteria and fungi. In addition to their peculiar filterable properties, these viruses are highly infectious, can propagate themselves rapidly and abundantly within the cells of the living plant, but not in any other type of medium. Recent information indicates that a certain few viruses can be separated out of the plant juices in a crystalline form and still retain their infectious nature for an indefinite period.

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Figure 1.—Mild mosaic.

Because of the lack of knowledge of the nature of the causal agents, identification of these diseases must be based on symptoms. This leads to confusion. A virus may produce certain types of symptoms on one variety of potatoes, but when transferred to another

variety, an entirely different type of symptom may result. Under one set of environmental conditions, a virus may produce certain types of symptoms on any given variety, while under different environmental conditions the manifestations of the virus on the same variety are entirely different. This accounts for the multitudinous number of virus diseases described.

The infective principles causing virus diseases in potatoes are systemic in the plant and can therefore be found in any portion of the plant. Potato tubers from diseased plants are invariably capable of producing diseased plants of the same nature as those from which the seed tubers came. Some of the viruses are readily transmitted by mechanical means, while others are not. Insects play an important role in transmitting the viruses. Various species of aphids, insects with sucking mouth parts, are responsible to the greatest extent. In the case of spindle tuber, in addition to the role played by aphids, such insects as the grasshopper and Colorado potato beetle are likewise capable of spreading the virus. These latter species of insects possess biting mouth parts.

Based on symptoms, the following virus diseases of potatoes are recognized in Idaho: (1) mild mosaic, (2) crinkle mosaic, (3) rugose mosaic, (4) leaf roll, (5) witches broom, (6) spindle tuber, (7) calico, and (8) giant hill.

Mild mosaic

Mild mosaic is characterized by a mottling in the leaves of affected plants. Lighter green areas of irregular size are scattered throughout the normal green of the leaves, these areas being irregularly located in the leaf blades and not limited by the veins. A slight crinkling accompanies the mottling. This crinkling, if near the edge of the blades, causes the edges to be wavy. The plants are slightly dwarfed. Tests have shown that the yield of infected plants is reduced by about one third in comparison with that of healthy plants.

Crinkle mosaic

Even for the initiated it is sometimes difficult to distinguish between crinkle and mild mosaic. The symptoms of both troubles blend into each other to such an extent that differentiation is sometimes impossible. It could be said, therefore, that crinkle mosaic is an exaggerated case of mild mosaic—not that they are the same or that they are produced by the same virus. The mottling is more distinct and the lighter colored areas are more numerous. The crinkling is quite distinct and in proportion to the mottling present. Under conditions of high temperature and high light intensity, the mottling has a tendency to become masked. The crinkling, however, still persists, thus enabling one to identify the disease.

Crinkle mosaic is more severe on the yield of infected hills than is mild mosaic. It has been determined experimentally that the yield of infected hills is reduced as much as 50 percent below that of healthy hills.

Figure 2.—Rugose mosaic.

Rugose mosaic

Of the mosaic diseases, rugose mosaic is the most readily distinguishable and also the most destructive. Dwarfed plants are invariably produced by diseased tubers. The leaves of such plants

are mottled, the mottled areas being smaller and more numerous than in either mild or crinkle mosaic. This mottling, as in the case of crinkle mosaic, is masked by high temperatures, but a distinct crinkle is always present.

A closer examination of the diseased plants will show some of the veins on the underside of the leaves, particularly the lower ones, to be killed. This dead tissue can be followed throughout the leaf blades as thread-like lines. Death of the tissue extends from the veins into the intervenal areas, resulting in irregular dead areas. In severe cases the entire lower leaves are dead and have fallen away from the stem. In the case of current-season infections, dead veins and areas of the leaves may appear in the upper portions of the plant. This latter type of killing may take place in the absence of distinct mottling and crinkling.

Rugose mosaic results in a marked reduction both in size and yield of diseased plants. A 75 percent reduction in yield can be expected from diseased plants. Affected plants die prematurely.

Figure 3.—Leaf roll.

Leaf roll

This trouble is readily recognized when one once becomes familiar with the symptoms. Plants affected with leaf roll are completely devoid of mottling. The distinguishing symptom is the rolling upward of edges of the leaflets along the midrib, giving them a "rabbit ear" shape. This rolling is generally more noticeable in

the lower leaves but likewise appears in the upper ones in severe cases. In addition to the rolling of the leaves, the latter are somewhat brittle to the touch. Attempts to bend the leaves result in the breaking of the tissue. Affected plants will rattle when shaken. The diseased plants assume a lighter green color than the healthy ones and are reduced in size. Occasionally some tubers from diseased plants show a net necrosis. This latter symptom cannot always be depended upon as a true diagnostical character, however, for there are other causes producing the same effect. The yield of plants arising from seed tubers affected with leaf roll is reduced from 50 to 75 percent.

Spindle tuber

This disease is the only virus disease which shows typical symptoms in the tubers. Tubers from plants affected with spindle tuber become elongated and pointed at one or both ends. In the round varieties, such as Bliss Triumph, the pointed ends are not so noticeable as in the case of Netted Gems.

The aerial portions of the affected plants show typical symptoms. The type of growth is quite erect due to the acuteness of the angles between the lateral branches and the main stem. This narrowness of growth is accompanied by a stunting. There are no mottling symptoms produced. Under nonirrigated conditions the true spindle tuber plant is difficult to distinguish because of the fact that under conditions of low moisture and high temperatures, normal healthy plants sometimes show symptoms that can be mistaken for true spindle tuber symptoms.

A reduction in yield of 40 to 70 percent accompanies the decreased growth in affected plants.

Witches broom

Plants produced by tubers affected with the witches broom virus are readily distinguishable from plants affected with any of the other viruses. This disease generally results in a very bushy, thread-like type of growth. Each eye of the affected tuber produces numerous sprouts which never reach any appreciable size. The growth does not even resemble that of a potato in many cases. If growing under optimum conditions of temperature and humidity, such as in a greenhouse, the affected plants remain green for several years, gradually becoming more dwarfed the older the plants become. The leaves are decreased in size and rounded. Tubers are increased in number and decreased in size. Occasionally the stolons ramify for some distance from the plant, ending in a sprout above ground. Several small tubers will be found along such stolons, giving the impression that the stolons grew through the tubers. Seed potatoes which bear long thread-like sprouts instead of short, stubby sprouts should be discarded as possibly being affected with witches broom.

Calico

Calico is a virus disease characterized by the presence of large yellow to white, irregularly shaped spots in the leaves of affected

Figure 4.—Witches broom.

plants. There is a partial to complete lack of green coloring matter in such spots. Only occasionally are all of the leaves affected. Even so, the virus seems to be systemic in the plant, for tubers from af-

fected plants will perpetuate the trouble. Plants affected by the disease appear normal in all respects except for the spotting. Crinkling is entirely lacking, nor is there any noticeable dwarfing of the plants.

Figure 5.—Psyllid yellows.

Giant hill

Occasionally there is reported from various sections of the State a disease known as giant hill. The chief distinguishing characteristic of this disease is the coarse rank growth which the affected plant assumes. This feature becomes more noticeable as the remainder of the plants in the field approach maturity. After the first light frosts, the giant hill plants are still green, at which time their coarse type of growth is emphasized. The yield of tubers of affected plants is slightly increased, as is the average size of the individual tubers. Many such tubers are unfit for market, however, because of the prevalence of cracks and rough type of growth. The seed grower must guard against the selection of such plants for seed on the basis of their vigor.

Psyllid yellows

During some seasons there occurs in some sections of the State, particularly in the southeast, a virus-like disease known as psyllid yellows. It is not a true virus disease because of various reasons: (1) the disease is induced by the feeding of the young of the tomato psyllid, an insect whose adult stage somewhat resembles leafhoppers; (2) when these insects are removed from the plant, recovery by the plant has been noted; (3) the trouble is not transmitted from one crop to the next through the seed tubers; and (4) the infective principle cannot be transferred from a diseased plant to a healthy one by any known mechanical means, as is the case with a number of typical viruses.

The first symptoms to appear are the upward rolling of the basal portion of the leaflets of the younger leaves and a marginal yellowing of such leaflets. A certain amount of rigidity accompanies the rolling. The rolled portions of the plant assume a reddish color in such varieties as Bliss Triumph and Irish Cobbler. In more advanced stages the older leaves roll over the midrib, become yellow, and die. New leaves and branches may appear on the old stems. The internodes are shortened, and the nodes enlarge. Lateral buds are stimulated to activity and may develop small aerial tubers or short stocky rosetted shoots.

In cases of early infection, setting of tubers is retarded or completely prohibited. Older plants when infected may produce long, tortuous stolons, the terminal buds of which may develop a new shoot instead of a tuber at some distance from the mother plant. Many small tubers may be produced along such stolons. The buds on tubers produced by affected plants can germinate immediately without passing through a rest period.

Losses of from 50 to 100 percent have been reported as being due to this disease.

Since the tomato psyllid is so peculiarly responsible for the trouble, in that it apparently injects, while feeding, some toxic principle which becomes systemic in the plants, and because recovery by the plants is possible if the insect is removed, control should be based on the matter of preventing the insect from feeding. In those potato-growing sections where the insects persist from year to year and are present in sufficiently large numbers to warrant the use of control measures, spraying with lime-sulphur spray (1-40) has been recommended. The number of applications and times of applications will depend upon the date of the first appearance of the insect and the population of the insects at any given time.

Control of Virus Diseases

It would be useless for the grower of commercial potatoes to attempt to control the virus diseases in the commercial fields. When such diseases occur in the fields and are there because diseased seed has been used, it is then too late to attempt to control them. To do so would necessitate roguing, which would result in a decreased yield, and thus a decrease in the grower's income. Diseased plants do produce some crop but not in proportion to healthy plants. To secure maximum yields, the commercial grower should use seed that he knows to be free from virus infection. Certified seed assures the grower that such a product will result in stands that contain a minimum of the virus diseases. It would be well for the commercial grower who buys his seed to inspect seed lots as they are growing, whenever possible, to satisfy himself as to the quality of the seed he desires to purchase.

For the grower who produces seed, several methods are available by which the virus disease content of any seed lot can be kept at

a minimum. Eradication is the basis of all these methods. Any seed lot, during the growing season, should be kept free of all virus diseases. This will entail much time, energy, and patience on the part of the grower at all times.

A field of seed should be well isolated from other fields, at least 300 feet. Different varieties should not be in close proximity, even if they are well rogued, for some varieties are much more susceptible than others, and also because of the nature of some viruses. Roguing should be practiced constantly throughout the growing season. If roguing is delayed until late in the season, insects spread the virus. Since it requires 10 to 14 days from the time infection takes place until visible symptoms appear, it is quite possible that if roguing has been delayed, spread of the infection will have taken place, and before symptoms show, frosts have killed the tops to such an extent that it becomes impossible to pick out such late infected plants. Such infected plants are harvested with the healthy plants. Diseased tubers are mixed with healthy ones, and thus it is that a certified lot of seed oftentimes contains so many diseased plants the following season.

The accepted method for a seed grower to follow in controlling virus diseases is as follows:

Seed plot. Every seed grower should have a seed plot of sufficient size to produce enough seed for the next year's commercial seed field. This plot should be isolated from other potatoes. To facilitate roguing this plot, it should be planted by the tuber-unit method. Such a method places all of the seed pieces of one tuber consecutively in the row. If the original tuber were diseased, all of the progeny of such a tuber are grouped and easily eliminated; whereas if the plot had been planted by the mass planting method, the several plants from the same tuber would be scattered throughout the field, resulting in the possibility of one or more of them being overlooked. Constant and careful roguing of the plot will decrease the amount of roguing necessary in the commercial seed field the following year. It would be advantageous to use "single drops" whenever possible in planting this plot. Such a practice would assure stronger and more vigorous plants, and subsequent roguing would be facilitated.

Sufficient seed from the seed plot should be saved for the next year's plot. The remainder would be used to plant the commercial seed plot. If care has been taken in roguing the seed plot, it will be found that one or two roguings for the season will suffice in the commercial field.

Neither spraying nor seed treatment is of any avail in controlling virus diseases.

Parasitic Diseases

Parasitic diseases are caused by fungi, bacteria, and other living organisms. To be parasitic, an organism must live on a living plant, its host, and derive its nourishment from that host. Some

organisms exist on dead organic matter, as they sometimes do in the soil. When they exist in this manner, they are known as saprophytes and as such give us no trouble. Upon occasion a fungus organism may vary its habit of existence from that of a parasite to that of a saprophyte, or vice versa. In fact, many of the organisms that cause trouble as parasites exist for part of their life cycle as saprophytes. This condition naturally complicates the matter of control.

Fungi are one of the lowest forms of plant life. They are commonly called molds. The mold is a mass of delicate, cobwebby threads called mycelium, each individual thread being microscopic in size. Fungi reproduce by means of spores. These correspond to seeds in the flowering plant. Spores are capable of existing in a dormant condition for various lengths of time, retaining their ability to germinate upon the advent of favorable conditions of moisture and temperature.

Bacteria are likewise a low form of plant life. They are for the most part single-celled plants, much too small to be seen by the naked eye. The bacteria causing plant diseases multiply by simple division.

Fungus Diseases

Rhizoctonia

Of the diseases caused by fungi, rhizoctonia is probably the most prevalent in Idaho. Affected plants show various types of symptoms which, in many cases, appear to bear no relation with each other. The type of symptom appearing will depend upon such factors as climatic conditions, soil, or stage of development of the plant at the time of infection.

The outstanding symptom and the one most readily recognized appears on the tubers in the form of irregular to round, dark brown to black patches. These patches, called sclerotia, vary in size from mere specks to one-fourth inch in diameter and may vary from a mere film to one-thirty-second inch in thickness. They can be picked from the surface of the tuber with the fingernail but are not readily, if at all, washed off. For this reason they are commonly known as "the dirt that will not wash off."

These sclerotia are a resting stage of the fungus itself. The fungus mycelium compacts itself into a dense mass, permitting it to withstand adverse environmental conditions. Thus, adhering to the tubers, the sclerotia pass from one crop to the next and act as a source of infection for the current season's crop.

The occurrence of the sclerotia on the tubers does not result in injury to the crop. If very many are present on the tubers, they detract from the appearance of the tubers and thus lessen the market value of the crop. The culinary value of such infected tubers is not lessened in the least.

Infection by this organism on the growing plant, however, does

result in injury. The symptoms accompanying this injury may appear as yellowing and purpling of the leaves, rosetting, leaf rolling, aerial tubers, or stem lesions. These symptoms may appear singly or in combination. Invariably, lesions occur on the underground stems and stolons and are the result of the invasion of surface tissues of such parts of the plant by the mycelium of the fungus. Such spots are rusty in appearance and vary in size. Lesions may occur to such an extent that the proper transfer of nutrients from the roots to the aerial portions of the plant is interfered with. Thus, the other types of symptoms mentioned above will occur.

When severe lesions occur on the sprouts before they emerge, such sprouts may be rotted off. Several successive sprouts may be

Figure 6.—Rhizoctonia. Sclerotia on tuber.

affected likewise, resulting in an uneven stand of potatoes. If such lesions occur when the plant is reaching maturity, the main stem below ground is rotted off, the leaves will be rolled and off-color, or aerial tubers may be formed. In either event, yield and quality will be materially reduced.

Under conditions of high humidity and cool temperatures, the fungus will appear on the stems immediately above the ground line. Here a white to gray mycelial mat will occur capable of producing the spores of the organism. This symptom is readily overlooked since it so seldom occurs.

Several methods are available by which the effects of rhizoctonia infections can be kept in check. The amount of infection occurring

in soils with a temperature above 75° F. is negligible. Of course, the temperature of the soil cannot be controlled, but the influence of low temperature on the activity of the organism can be lessened by waiting as long as possible in the spring before planting, or until the time of greatest influence of cold, wet weather has passed. The producer of early potatoes in some sections of the State naturally will be unable to comply with such a recommendation.

Figure 7. — Rhizoctonia. Note manner in which stems have been rotted off.

Rotation of crops will lessen the possibilities of losses from rhizoctonia. Care, however, should be exercised in the choice of crops to be included in the rotation. Sugar beets, for example, are quite susceptible to the organism. Grain crops are in all probability the least susceptible.

The use of clean seed cannot be overemphasized. Even though the organism persists saprophytically in the soil, nothing is to be gained by introducing more inoculum into the soil by the use of seed tubers whose surfaces are largely covered with sclerotia of the organism. Seed treatment should therefore be practiced. Any standard method of treatment carried out according to recommendations will suffice.

Fusarium wilt

Fusarium wilt is caused by one or more species of fungi. These organisms are commonly present in most southern Idaho soils. In many instances severe infection occurs when potatoes are planted on virgin soils that have never grown a cultivated crop. It appears that any environmental factor which limits the growth of the plant results in more fusarium damage. Very little, if any, difficulty, due to this disease, is encountered in the potato districts of the State north of the Salmon river. Climatic factors are not conducive to this disease in these districts.

Potato plants usually are infected from the soil through the roots or through the seed piece. Although the casual organisms may be carried over in the seed, it is doubtful whether much of the disease in Idaho is a result of seed infection. Certainly the most common and serious type of infection is from the soil.

Under Idaho conditions fusarium wilt symptoms usually are not noticeable until the plants are about 1 foot in height, but they may appear at any stage of plant growth. In the irrigated sections of the state, the disease usually appears in August and becomes more apparent as the season advances. If very severely infected seed is planted, considerable seed piece decay and poor stands may result.

The first symptom of the disease is a noticeable yellowing and drooping of the lower leaves of the plant. These leaves eventually die and fall off. Following this primary symptom, there is usually a progressive dying of leaves upward on the stem and the entire plant dies prematurely. Often only one stem in a hill will die, or only the leaves on one side of a stem will die. All stages of the disease may be found in one field. If infection in a field is slight, the plants may die only a week or two before normal maturity, but if the infection is severe, the plants may die before the tubers have reached full size, thus reducing yields considerably.

The lower part of the potato stem infected with fusarium shows a brown discoloration in the vascular system. This discoloration often appears throughout the stem at considerable distances above ground and is particularly noticeable near the junction of the leaves with the stem. It has been shown that potato plants can have brown internal stem discolorations without the presence of a fusarium organism. This type of discoloration usually is attributed to dry conditions and high air temperatures. In Idaho the discoloration usually is associated with the presence of a fusarium organism. One species of fusarium is capable of involving the pith of the stem. In such cases, brownish flecks of dead cells are scattered throughout this tissue. The flecks are more numerous in the vicinity of the nodes.

In the tuber, fusarium wilt often causes a distinct browning of the vascular ring, which is especially noticeable at the stem end. The amount of discoloration in the tuber depends largely upon the severity of the disease and the time of the season at which infection takes place. Here again this vascular discoloration is not always associated with the fusarium wilt disease. Consequently, a tuber which has vascular discoloration does not necessarily have fusarium wilt and thus this discoloration cannot be used as a basis for discarding tubers for seed.

Environmental factors markedly influence the time of appearance and the severity of the disease in Idaho. Experimental evidence indicates that infection is favored by high soil moisture. After infection has been accomplished, development of the wilt is faster in dry soils and high air temperatures. On land where low and high spots occur in the field, wilt appears earlier in the season in the poorly irrigated spots.

The disease usually appears earlier in the season and affects the plants more on soils of low fertility than on soils of high fertility.

It especially is more noticeable on light sandy soils where it is more difficult to control moisture content and fertility.

Complete control of fusarium wilt probably is impossible, at least until varieties are developed that are resistant to it. However, growers in southern Idaho can follow cultural practices which will delay the appearance of the disease sufficiently in most years so that yields will not be materially reduced.

Figure 8.—Fusarium wilt. Diseased plant at left. Healthy plant at right.

The primary prerequisite in controlling the disease is to maintain the soil at a high fertility level. Fertility implies more than just maintaining an adequate supply of nutrients. In addition to nutrient supply, the soil must be kept in good physical condition and the organic matter content must be maintained. These requirements can be met if a grower will follow a good rotation system and supplement it with the addition of barnyard manure and, if necessary, with commercial fertilizer. Wherever possible, potatoes should follow a legume (preferably alfalfa or clover) in the rotation, and this green material should be plowed under.

Where wireworm is not a problem, rotations including red or sweet clover and plowing under the green material in the spring just before planting, have given excellent results. Where wireworm is present, alfalfa should be used in preference to the clovers and if possible the third cutting should be plowed under in the fall preceding potatoes. In many areas of southern Idaho it is necessary to apply phosphate fertilizer to get good growth of the legume crop and unless it is supplied, the yield of the succeeding potato crop

will likely be lower than if maximum legume growth had been obtained.

For the best control of fusarium wilt as well as for best yields, potatoes should not be planted on the same land more than 2 years in succession, and preferably not more than 1 year.

Evidence at hand indicates that the primary cause of early dying of potato vines in southern Idaho is due to fusarium infection which condition is aggravated by lack of available nitrogen. Lack of available nitrogen is so important that, under some circumstances, this deficiency can be mistaken as the primary cause of dying. However, it is believed that the two factors are so interrelated that under conditions of low nitrogen where growth is limited, the plant is more subject to infection by the disease organism. The addition of commercial nitrogen fertilizers has in many instances materially delayed the appearance of the disease and resulted in yield increases of 20 to 70 sacks per acre.

Fusarium tuber rots

As was the case with wilt, tuber rots are caused by several species of the Fusarium organism, either acting alone or in combination. Some of the same species responsible for wilt are responsible for the rots. For the most part, the rots occur after harvest and after the crop has been stored, but occasionally rotted tubers will be found previous to harvest. In the latter case the rot will be generally watery in consistency. If the points of infection are located on the stem ends of the tubers, the term "stem-end" rot is applied, while if located at the blossom end of the tubers, the term "jelly-end" is applied. Under conditions of high soil moisture, the lenticels (breathing pores) are enlarged. Infection will take place through these channels, resulting in a watery, wet rot appearing at any point on the tubers. The color of the underlying tissues is dark brown to black and watery in consistency.

The greatest loss due to rotting of tubers occurs following harvest. The symptoms will depend upon the species of the organism involved and upon environmental conditions. In general, sunken, shriveled, wrinkled, or broken areas occur on the tubers at any point. The broken-down tissues are brown to black in color, and are more or less covered with white or pink colored tufts of the casual organism. The rot may be wet and jellylike, mushy and leaky, or dry and brittle, with or without cavities lined with the tufts of the organism. These rots are never slimy, even when wet. It occasionally happens that the entire pith portion of the tuber is consumed by the rot, resulting in a hollow shell.

The source of infection of the tubers is the organism scattered in the soil, on the containers and implements, and in storage houses. Although infection of the tubers may take place previous to harvest, the probabilities are that most of the infection takes place at the time of or subsequent to harvesting and then primarily through

wounds. When a tuber is wounded, the tissues immediately tend to repair the damage by impregnating the first few layers of cells surrounding the wound, with impermeable material. The result is that the wound is completely walled off. This impermeable layer

Figure 9.—Various types of Fusarium tuber rots.

prevents the rot-producing fungi from establishing themselves in the wounds, preparatory to invading the internal tissues of such wounded tubers. The rate at which this suberized layer will be

built up, will depend upon the variety of potato and the environmental conditions to which the wounded tubers are subjected. Within limits, the higher the temperature and humidity to which the wounded tubers are subjected, the more rapid the repair. Prevention of injury is of major importance in the control of tuber rots, and is a more easily attainable goal than is the healing of

Figure 10.—Early blight. (Cornell Ext. Bul. 135)

wounds after they have been produced. Reduce tuber injury and a decrease in the loss due to rots will result.

Newly harvested tubers should be thoroughly dried, insofar as it is possible to do so, before being placed in storage. A tuber is part of a living plant and, when placed in storage, life processes continue throughout the storage period. Tubers breathe and in so doing give off moisture, which is particularly true of newly dug tubers. When such tubers are placed in storage in deep piles, the moisture given off by the tubers may accumulate in the pile. This moisture, coupled with the heat evolved in the pile, produces ideal conditions for the rot-producing organisms. The answer to the problem, therefore, is to cure the tubers as thoroughly as possible before placing in storage and provide good aeration in storage with temperatures ranging between 35° to 40° F.

Before placing the newly dug crop in storage, the walls and floor of the pits should be sprayed with a good fungicide, such as either of the following: 1 pound copper sulphate in 10 gallons of water, or 1 pint formalin in 10 gallons of water. Either spray will eliminate to a great extent many of the rot-producing organisms which persist in a storage compartment from one year to the next.

Early blight

This fungus disease occurs occasionally from year to year in the state, but it is generally not serious. The losses caused by it are primarily due to the fact that the tops are centers of infection. In severe cases the tops are killed prematurely, thus materially reducing yields. A close examination of affected tops will disclose the presence of large brown spots on the leaves. These spots are made up of concentric rings which produce a "bull's-eye" effect. Occasionally the tubers are involved, upon which will occur small, circular spots. This damage in itself is not serious, but such spots afford a means of entrance for rot-producing organisms.

In general, neither the number of fields involved nor the severity of infection in any one field is of sufficient importance to cause much concern. However, should attacks by the fungus causing this disease be a source of concern, spraying with Bordeaux mixture (5-5-50) will check the spread of it. Since the organism lives from year to year on old plant parts, the destruction of old vines should be practiced.

Leak

This trouble is distinctly a tuber rot of fungus origin and is encountered primarily in the early-potato districts of the State.

When potatoes are harvested during the hot weather of summer, for immediate shipment, and are not immediately removed from the fields to cooler temperatures, this trouble may appear in the crop before such tubers are graded, preparatory to loading and final inspection. Or, it may appear, in the loaded product, before the cars reach their destination.

The trouble is characterized by a very watery type of rot. The causal organism gains entrance to the tubers from the soil through wounds. At these points there first appears a brown discoloration. Within limits, the higher the temperature, the more rapidly does the organism involve the inner tissues of the affected tubers. Badly infected tubers are brownish and water-soaked over their entire surfaces and, if not disturbed, retain their shapes. Water may ooze from several broken places in the skin, in which condition such tubers are known as leakers. Upon application of pressure the tuber collapses. The interior of infected tubers, when broken, is usually a dirty white color. The appearance of wet patches on sacks should be regarded with suspicion.

Control of the trouble resolves itself into a matter of care in harvesting in order to reduce injuries to a minimum. Discarding all injured tubers is likewise important. If early potatoes are being harvested for immediate shipment, they should be graded and placed in cars as soon as possible.

Jelly end rot

The rhizoctonia organism, or any one of several fusarium organisms, producing fusarium wilt and tuber rots, are suspected as

Figure 11.—Jelly end rot.

being the cause of jelly end rot. When any one of these organisms sets up a rot on either end of a tuber, previous to harvest, the resulting rot is known as jelly end. If the rot appears on the eye end of the tubers, it is generally confined to those which are pointed in this region, or on second growth knobs. If on the stem end of the tubers, it has been observed that such affected tubers are quite generally more regular in shape.

The observation has likewise been made, that some fields consistently produce jelly ends, regardless of the quality of the seed used to plant the field. It has therefore been suspected that either growth conditions, or fertility of the soil, may be responsible for the trouble. Experimental evidence in regard to these points is conflicting. It is quite possible that growth conditions have an indirect effect in the occurrence of the trouble

The involved tissues have a clear, jelly like consistency. After harvesting and having been placed in storage, the affected parts shrivel, and progress of the decay is retarded, or it develops no further.

Since the rot develops in the soil previous to digging, recommendations of control are difficult to make. Any procedure that would prevent the development of pointed tubers might lessen the occurrence of the trouble. This could be accomplished by providing growing conditions most satisfactory for the growth of the crop.

Silver scurf

The fungus parasite causing silver scurf is limited in its distribution to the northern counties of the State. In this section the symptoms are so inconspicuous that the disease is seldom noticed. No losses are recorded because of the disease.

The organism only attacks the tubers. Here the infected areas assume a light brown or tan color, with a glazed appearance. These areas are more noticeable when the surfaces of the tubers are moistened. Since it is only the outer tissues of the tubers which are affected, the diseased spots have a tendency to shrivel as time progresses. The organism can sporulate on the stored potatoes, thus making it possible for it to spread in the bin.

Since the disease is of such minor importance, no specific recommendations are made for its control.

Bacterial Diseases

Ring rot

This bacterial disease was definitely found in Idaho in July 1939. Indications are that it was present earlier than that. Because of the potentialities of the disease, it is the cause of much concern on the part of everyone in the State interested in potato production.

In experimental tests severely infected seed tubers either rot in the soil before producing a sprout or produce weak sprouts which never fully develop. Such plants are short, light green to yellowish in color, upright in growth, and more or less rigid in texture. Eventually the edges and tips of the leaves become burned. This condition gradually spreads and eventually involves the entire plant. Death results when the plants are but a few inches tall.

Plants from slightly infected seed pieces may or may not show symptoms. Typically rotted tubers have been harvested from plants which showed no visible symptoms. When symptoms do occur, they appear late in the growing season. The first symptom

may be a slight rolling of the leaflets on affected stems. There is no recovery from this rolling as would be expected in plants affected by dry growing conditions. Rolling of leaves is followed by wilting which, in many cases, involves but one stem in a hill. This wilt might be called a "quick" wilt in that it appears very suddenly and is similar to that due to the cutting off of the underground stems by gophers. There is very little if any loss of green color accompanying this "quick" wilt. Such infected stems die without much loss of color. The fact that but one stem in a hill is at first

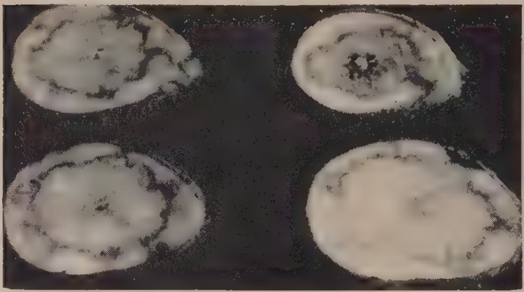

Figure 12.—Ring rot, showing tuber and plant symptoms. Upper—Cross-section of infected tuber showing manner in which the vascular ring or conductive tissue of potato becomes infected and discolored. Lower—Typical "quick wilt" type of symptom showing one stalk breaking down.

involved does not mean that the remaining stalks are free of infection. Eventually they likewise may break down. Various combinations of symptoms can be expected, ranging between those described as appearing in the younger stages of development of the potato plant, and those described as appearing at maturity.

Cross sections of wilted stems are either colorless or only slightly yellow to light brown in the region of the conductive tissue. Typically diseased stems are never discolored a dark brown to black in

the above-mentioned tissue, as is the case in fusarium wilt and black leg diseased plants.

An infected plant will invariably produce infected tubers, providing the vine is not killed prematurely. It must be understood, however, that some infected plants are unrecognizable as such and that these plants are capable of producing diseased tubers. Early stages of the disease in tubers produce no visible symptoms on the surface. Diseased tubers when cut show a yellowish to creamy discoloration of the conductive tissue, particularly at the stem end. If the infection has advanced very far, the discolored tissue will form an irregularly shaped ring slightly below the surface of the tuber. It might be expected that when tubers show this degree of infection, the tissues comprising the ring have become so disintegrated that that portion of the tuber outside the ring is separated from the inner portion, or core, of the tuber. If slightly squeezed, small drops of ooze will appear at various points on the ring.

The infection, which has entered the tubers from the stolons, eventually passes into the central portions of the tubers. The tissues thus affected develop a typical rot of a cheesy or crumbly consistency but with no odor. Tubers infected with the ring rot bacteria occasionally produce an odor and show a wet stringy type of rot. It is suspected that these two latter symptoms are the results of rot-producing organisms other than the ring rot bacteria which follow the initial invasion of the ring rot organism. In late stages of decay, the rot is noticeable on the outside of the tuber. In some cases, infected tubers will show a distinct cracking or checking of the surface accompanied by a characteristic dull color.

Control of bacterial ring rot is largely a matter of avoiding the disease and limiting its spread in the cutting, handling, and planting of seed stocks. Several practices can be recommended:

1. *Do not plant any seed which is known to be infected with ring rot regardless of how slight this infection may be.* Examine carefully for ring rot, as late in the growing season as possible before frost, any fields from which you expect to use seed.
2. Do not use for seed any potatoes which have passed through a washer.
3. New, clean seed should never be placed in used potato bags or handled by machinery or placed in storage if there is any possibility of contamination from these sources.
4. Do not use potato machinery, baskets, sacks or other equipment which may have become contaminated until they are thoroughly disinfected.
5. *Disinfect the cutting knife.* A simple rotary disc-shaped knife can be rigged up to revolve in a disinfecting solution. The reservoir through which the knife rotates should hold at least 1 gallon of disinfectant, and the level should be maintained so as to completely disinfect the knife. B. K. solution at a strength of 1 part to 125 parts of water can be used, but the solution should be discarded and replaced with a fresh amount after each 10

sacks of seed cut. Boiling water also is very effective and less costly. Care must be exercised to keep the water boiling with a hot plate or other device under the reservoir, and to keep the level up to the required point. It is not necessary to change the solution when boiling water is used. *Disinfection of the cutting knife probably is the most important method of preventing spread of the disease* and is recommended as a general practice even when the seed lot is thought to be free from ring rot infection. This practice may also prevent the spread of some other potato diseases.

6. Handle the seed as little as possible while cutting and planting.
7. The assist-feed type of planter is preferred to the picker type.

When potato growers find ring rot in their fields, special effort should be made to clean up the infection before bringing in new seed. Several steps can be recommended for this clean-up job.

1. *Dispose of all potatoes on the farm.* Where fields are infected, the potatoes should be left in the ground as long as possible and marketed from the field if possible without being put into the cellar. This permits the infected potatoes to break down so that the late dug potatoes are less likely to break down in storage or in transit. Marketing directly also avoids contamination of the cellar.
2. *Disinfect cellar thoroughly* if a contaminated crop has been stored in it. Clean up mechanically, removing all loose dirt and old potatoes, sprouts, etc. Spray thoroughly with a solution of copper sulphate, 1 pound per 10 gallons of water. This is a good practice to follow regardless of ring rot and should be done as soon as potatoes are all removed in the spring.
3. *Disinfect all machinery* including planter, digger, grader, baskets, etc. Remove all dirt from implements and drench with 5 percent lysol solution.
4. *Disinfect sacks, gloves, etc.* Boil in water for 5 to 10 minutes or more.

Common scab

The organism causing common scab is naturally present in some of the state's virgin soils. Such ground, when found to be severely infested, should never be used for potato production.

Since tubers with severe scab lesions are classified as culls, the salable product of many fields is reduced materially. Housewives object to using scabby potatoes because there is so much waste to them.

Scab is a disease that appears only on the tubers as rough, pitted areas, varying in size. These spots will appear round to irregular in shape and either shallow or deep. Occasionally the spots are raised and warty-like in appearance and the affected tissue will have a corky texture. Because the tops are not affected, the trouble is not detected until the crop is harvested.

Control of the disease resolves itself into several lines of attack.

The organism causing the trouble prefers alkaline conditions for its greatest activity and any practice that would tend to make the soil less alkaline or slightly acid in reaction would go far in controlling the trouble. Some growers add sulphur to the soil in varying amounts which produces acids in the soils, but the addition of it to high alkaline soils would be too costly. Slight relief can be obtained by plowing under a green manure crop. *Never add lime to soil intended for potato production.* It is likewise inadvisable to dust the cut seed with lime. Seed treatment will control any infection on tubers to be used for seed.

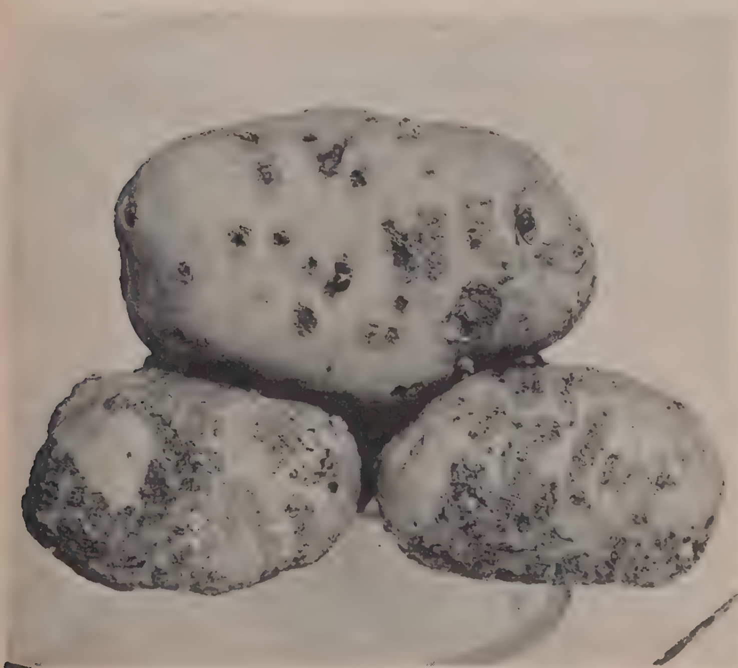

Figure 13.—Common or corky scab.

Experience has shown that even if the causal organism is a soil inhabitor, rotations of sufficient length will aid in controlling the disease.

Idaho growers are fortunate in that the most popular potato they grow, and the one best adapted to Idaho conditions, is one of the most resistant varieties in respect to common scab. The Idaho Russet, Russet Burbank, or Netted Gem is quite resistant and is the variety to use on slightly scabbing soil. Thin-skinned varieties, such as Bliss Triumph, Idaho Rural, and Early Ohio, are quite

susceptible and should not be used in soils infested with the scab organism.

Blackleg

There are several points in connection with blackleg that are difficult to understand, one of them being the matter of the sudden appearance of the disease in fields from seed which had previously been free of the trouble. However, in view of the fact that the bacterial organism causing this disease is one producing a soft rot of vegetables, some insight is afforded as to the explanation of this peculiar response. The casual organism is universally distributed. Any injury to the tubers affords an opening for the entrance of the bacteria. Likewise, high amounts of moisture seem conducive for the greatest activities of this organism.

Figure 14.—Blackleg. Two plants on left diseased. Plant on right healthy.

Observation indicates that ideal conditions are brought about by the storing of frozen tubers. As such tubers thaw out, abundant moisture is liberated from the broken-down cells. Wet, poorly ventilated cellars likewise afford ideal conditions for the bacteria. Potatoes stored in such conditions are likely to break down rapidly with a wet rot. Fields planted with potatoes handled in either of the above fashions are apt to contain a high percentage of blackleg.

Any portion of the potato plant is subject to infection by the bacteria causing the disease. In general, however, the centers of

infection are the seed pieces, stems, and tubers. Invariably when a plant is infected, the seed piece will break down first. Seed-piece decay, when produced by the causal organism alone, assumes a watery appearance. Seed-piece decay, however, is generally slimy and accompanied by an unpleasant odor. This type of rot is due to secondary rot-producing organisms which follow the initial infection.

From the seed-piece, the infection passes up the stem and into the stolons and newly forming tubers. If this type of infection takes place early in the growing season before tubers are formed and under conditions of low available moisture, the growth of the plant is checked. The leaves turn yellow and roll upward on the midrib.

Figure 15.—Three Netted Gem tubers showing lumpy effect produced by Root-knot nematodes.

When rolling occurs, the plants are erect in their habit of growth. Such plants are readily pulled from the soil because the lower extremity of the stem is badly rotted. Death of many plants will occur at this stage. Sometimes infection occurs so rapidly, yellowing and erectness of growth is lacking, being replaced with a distinct wilt. When this latter symptom occurs, the stems of such plants are blackened in the pith area. In such cases the pith may be completely destroyed in the lower regions of the stem. When such occurs, dark brown to black water-soaked-looking streaks can be noticed on the outside of the stem. These streaks, in some instances, can be followed upward and into the lateral branches.

When infection penetrates through the stolons into the newly forming tubers, a complete breakdown of the tuber may ensue,

particularly if the soil is unusually wet; or a small, decayed, sunken spot or a discoloration of the conductive tissue may occur on the stem end if the soil is dry. Here again, the type of rotting of the tubers may vary, as was the case of the seed-piece. The rot may be dry in nature, or it may be slimy, accompanied by an unpleasant odor due to the presence of saprophytic rot-producing organisms.

There is sufficient experimental evidence to show that the causal organism can persist from season to season in those tubers from diseased plants, whose conductive tissue shows discoloration. It is likewise possible for the organisms to persist in the soil. Such facts suggest some means which can be used in an attempt to combat the trouble. It is always expedient to use clean seed. Any tubers with a discolored vascular region when cut should be looked upon with suspicion. Before cutting, the seed should be treated. Directions for treatment can be found on page 34. Treatment will control any surface-borne organisms.

For the seed grower, when diseased plants appear in the field, they should be removed as soon as possible. Storage facilities should be well aerated, dry, and kept at a temperature of about 40° F. wherever possible.

Diseases Caused by Nematodes

Nematodes (eelworms) are microscopic round-worms. There are many species of these worms, some of which are free living in the soil and are never parasitic on plants. Others are parasitic on a wide range of plants for a part of their life cycle. Some of these parasitic forms, such as wheat nematodes, inhabit the above-ground parts of the hosts, while others attack the below-ground parts only. To the latter class belong the root-knot nematodes.

Root-knot nematodes

The root-knot nematode is capable of attacking a wide range of plants. No less than 1,155 different species of plants are listed by the Division of Nematology of the U. S. Department of Agriculture. The organism is distributed throughout the tropics and sub-tropics. In the United States, it is very prevalent in the south and has been reported from several states along the Canadian border. It has been observed that grains, although not immune to attacks of the worm, are highly resistant, and that the dandelion plant is very susceptible.

The common symptom accompanying an attack by root-knot nematodes is the presence of small swellings or "knots" on the roots. In heavy attacks, these "knots" so distort the roots that their normal function of transferring nutrients and water is interfered with, resulting in dwarfing and off-color to the upper portions of the plant. In the case of potatoes, these swellings are confined to the developing tubers. Thus, no aerial symptoms are visible. The surface of the tubers become quite warty in appearance, and small brown spots, 1/8 inch below the surface, appear in the flesh of the tubers. These spots contain the female worm and many small in-

visible eggs which have been deposited there. Thus it is that extreme caution should be exercised in selecting seed potatoes in order not to use infected tubers for seed.

The eggs may hatch within the tissue of the infested tubers. The young worms migrate into the soil. Here they must contact susceptible root tissue or else starve. They cannot migrate in the soil further than a few feet. Or, the eggs may have become liberated from the host tissue in masses called cysts due to the decay of the infested roots. Encysted eggs are quite ristant to adverse environmental conditions. Dissemination of the worms over great distances is due primarily to man and can be accomplished by one or more of the following agencies:

1. Shipment of infested seed and other plant parts.
2. Implements carry the worms from field to field.
3. The worms can be distributed in garbage.
4. Infested raw culls, when fed to stock, distribute the worms to the soil on which the stock is fed.
5. Irrigation water, having passed over infested soil, can distribute the worms.

There is no one single item that can be recommended to either control or to eradicate the worms from infested soil. It should be obvious that clean seed should be used on soil known to be free of worms.

It has been shown experimentally that the worms are killed by:

1. Thorough desiccation (drying).
2. Moderate heat (118° F. for 10 min.)
3. Extreme cold (0° F. for 2 hr.)
4. Starvation (2 to 3 years).

Cropping practices should be adopted that will make use of some of these facts. Rotations including grain should be used, in which the grain is seeded more heavily than usual to keep down weeds. Following removal of the grain, the soil could be fallowed for the balance of the year, keeping down all weed growth.

Since it is quite possible that the infestation is spotty in a field, such spots, if not too extensive, might be determined and not cropped for several years. This would permit the application of a thorough fallow for that length of time. Thus the use of the entire field would not be lost.

Do not use waste water which is known to have come from infested fields.

The ditch banks should be kept free of weeds.

Stem nematodes

The stem nematode is capable of attacking a wide range of hosts, both wild and cultivated. Within the species, however, strains occur which are highly specialized. Without a comprehensive test, it is impossible to say what other hosts might be involved with the potato strain. It is known that red clover, and alfalfa to a slight degree, are attacked by the stem nematode in Idaho. It is not known, as

yet, whether the worms attacking potatoes and the legume crops are capable of crossing over.

This nematode primarily infests the aerial portions of the plants, causing enlargement of the nodes and distortion of the stems and leaves. Tubers, in the case of potatoes, are the parts primarily involved. For this reason an infested crop of potatoes might be overlooked, until the crop is harvested. Infested tubers show discolored areas on their surfaces. The skin over such spots is frequently cracked and shrunken. Disintegrated tissue will be found within the cracks. Small pin point size holes also can be found penetrating the surface. Pockets of infested tissue occur beneath the

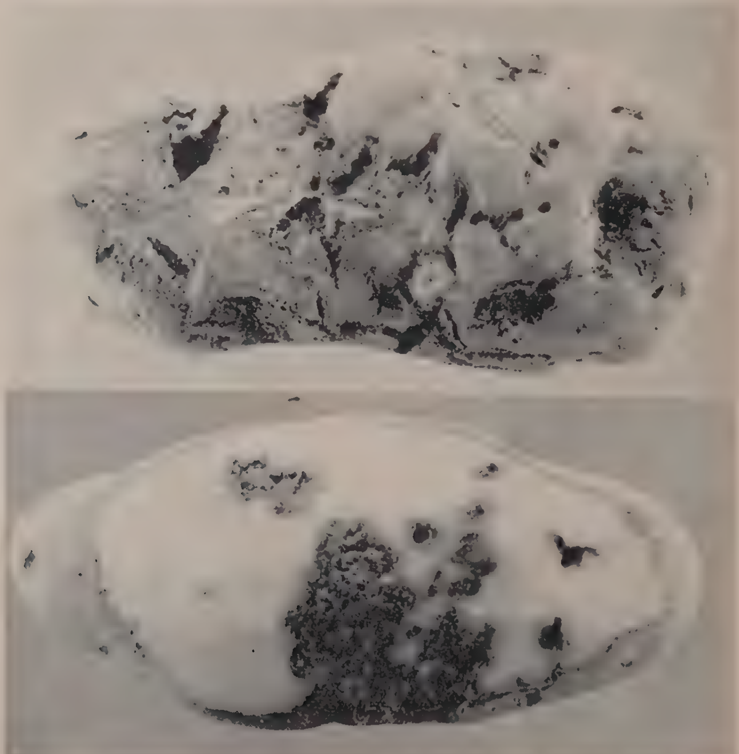

Figure 16.—Netted Gem tubers infested with stem nematodes. Above—Surface symptoms. Below—Internal symptoms.

surface, even when the latter shows only slight evidence of disease. Previous to the formation of the pockets, the infested tissues are at first chalky white in color, later changing to gray. Such tissue is soft and crumbly in texture. Rot producing fungi follow the

initial invasion of the worms and hasten the break down of the tubers.

Because of the fact that it is not yet known what other hosts, cultivated or wild, are attacked by this nematode, it is therefore not possible to recommend a rotation capable of eliminating the worms from the soil. It should be realized by growers, however, that infested tubers should not be transported from the field in which they are grown. This means, therefore, that infested tubers should not be used for seed. If fed to stock, the tubers should be cooked first. Care should be exercised by the growers, in moving stock and machinery into and out of a field known to be involved with the worms.

So far as is known, the infested area in the state is very limited in extent, involving only a few farms.

Nonparasitic Diseases

All nonparasitic diseases are caused by nonliving agencies. An unbalance of the nonliving environment may manifest itself by producing definite symptoms on a plant growing in such conditions. A disease is likely to occur if a plant is subjected to such factors as insufficient light, water, nutrients, or an overabundance of these factors. An atmosphere of toxic gases will produce definite symptoms in plants. These various agencies may react singly or in combination. Naturally, because of the nature of the causes, they are not transmissable from plant to plant.

Two nonparasitic diseases of potatoes are of common occurrence in Idaho. These are hollow heart and blackheart.

Hollow heart

Size of tubers and prevalence of hollow heart go hand in hand. The larger the individual tubers, the greater the possibility of hollow heart. It is characterized by a variously shaped hole in the center of the tuber, often surrounded by brownish, discolored tissue. Very little, if any, manifestation is apparent on the surface of affected tubers. Many large tubers, in a lot of tubers, might lead to suspicion, but not all large tubers are hollow.

Any factor or combination of factors which will result in a rapid growth of the tubers, particularly toward the end of the growing season, will in all probability cause some tubers to be hollow. Among such items can be enumerated excessive rainfall in the fall while the plants are still green, and an unusually long growing season.

If the trouble persists from year to year, delay date of seeding, use larger seed pieces, and plant closer. Whether to plant early or late and what distances, in an attempt to control size, will always be a problem.

It should not be forgotten that the occurrences of fall frosts have considerable influence upon the final size of the tubers.

Blackheart

Blackheart is a storage trouble, and its occurrence is definitely related or dependent upon temperature and amount of oxygen

present in the storage compartments. Potatoes are living, breathing things. They take in oxygen and give off carbon dioxide as does a human being. Limiting the oxygen supply, increasing the temperature of the storage bins, or a combination of both of these factors leads to trouble.

Blackheart can be recognized by the occurrence of a dark brown to black, irregularly shaped mass of tissue within the individual tubers. Occasionally this discoloration is accompanied by a hollowness, due to the shriveling of the discolored tissue. This hollowness should not be confused with that occurring in typical hollow heart.

Blackheart can be produced experimentally quite readily. By subjecting tubers to temperatures of 105°-110° F. for from 15-20 hours, blackheart will occur.

Conditions as they exist in the typical storage basements of the potato sections of the State are generally such that blackheart is prevented. Just so long as a plentiful supply of air is furnished in storage compartments whose temperatures are not excessively high, there should be no trouble. It could happen, however, even in such storage conditions, that the potatoes might be piled too deep, thus providing conditions inside the pile that are conducive to the occurrence of blackheart.

Seed Treatment

Experimental evidence and the experience of growers have shown conclusively that seed treatment is a good investment. It not only assures the grower of a comparatively clean product to be used for seed, but also improves the quality of the resulting crop. Unfortunately, seed treatment is not an absolute cure for all potato diseases for several reasons. First, the causal organisms of several diseases are borne internally in the seed tuber and thus so located that seed treatment will not reach them. Second, many disease-producing organisms persist in the soil. Then, there are those diseases which affect the tops only. It is obvious, therefore, that seed treatment will not be effective in these cases. Seed treatmnt therefore applies to those diseases, the causes of which are carried on the surfaces of the seed tubers. The diseases which occur in Idaho, the causal agents of which can be classified as being carried in this manner, are common scab, rhizoctonia, blackleg, and dry rot.

The organisms which cause these four diseases are all soil-inhabitors; that is, they persist indefinitely in the soil. It could, therefore, be asked, "Why treat the seed?" The answer is obvious. Seed treatment should be practiced in order to prevent the introduction of parasitic organisms into a soil that is free, or nearly free, of them. Although seed treatment is not a cure-all for all potato diseases, it can be expected that seed treatment will lessen the loss of stand from rhizoctonia, seed piece decay from blackleg or dry rot, or the possibilities of a cull crop because of common scab. Seed treatment is an inexpensive procedure because it requires no elaborate, expensive equipment, and the materials used for treating are

comparatively cheap. The small cost of treating is a worth-while investment and a good form of crop insurance.

Methods of Seed Treatment

Either of two chemicals can be used in potato seed treatment. They are formaldehyde and some forms of mercury. Formaldehyde is a gas which, when dissolved in water, is known as formalin. The latter is the form in which the material is found on the market. Mercury is one of the heavy metals and can be bought in two forms —mercuric chloride (corrosive sublimate) and in the so-called organic compound (New Improved Semesan Bel).

Figure 17.—Effect of presprinkling. Note that rhizoctonia sclerotia on tubers have germinated.

Formalin

Formalin can be applied in two ways—cold or hot.

Cold method. Mix commercial formalin (38-40 percent aqueous solution of formaldehyde) at the rate of 1 pint of the material in 30 gallons of water. Soak the seed tubers in the solution for 1½ hours. The time of treatment can be shortened if the tubers to be treated are sprinkled a day or two previous to treatment and kept moist during that time by covering with sacks. Presprinkling will increase the efficiency of any treatment with which it is used.

The formalin solution does not lose strength with use, nor does it corrode metal containers. Formaldehyde is poisonous and irri-

tating to the mucous membrane and therefore should not be taken internally, nor should it be breathed too freely. The treating tank should be located in a well-ventilated place.

Hot method. Because of the amount of time involved with the cold method of treatment, a method has been evolved whereby the temperature of the treating solution is raised and the time of treating materially decreased.

A solution of formalin is made up in the proportion of 1 pint of commercial formalin in 15 gallons of water. The temperature of this solution, in a suitable container, is raised to 125° F. The previously sprinkled potatoes are dipped in the warm solution for *4 minutes*, after which they are removed and covered for 1 hour. The potatoes should then be thoroughly dried, particularly so if they are placed back in storage. If the treating vat is large enough to accommodate 5 or more sacks, it would be well, previous to dipping the potatoes, to raise the temperature of the solution to about 128°-130° F. Thus, when the cold potatoes are placed in the

Figure 18.—One type of tank used in heating formalin solution. Plank sides, metal bottom, placed over hole in ground.

solution, the temperature will be at about the desired temperature for treating. It is convenient to leave the potatoes in sacks throughout the treating process.

Certain precautions should be taken in the process of treating. Do not dip at temperatures above 130° F. Four minutes' exposure in the hot solution is sufficient. If the potatoes are replaced in storage following treatment, *they should be thoroughly dried beforehand.*

Several types of apparatus can be used in which to heat the solution. In all cases, an accurate thermometer is necessary. The floating type of dairy thermometer is a desirable type.

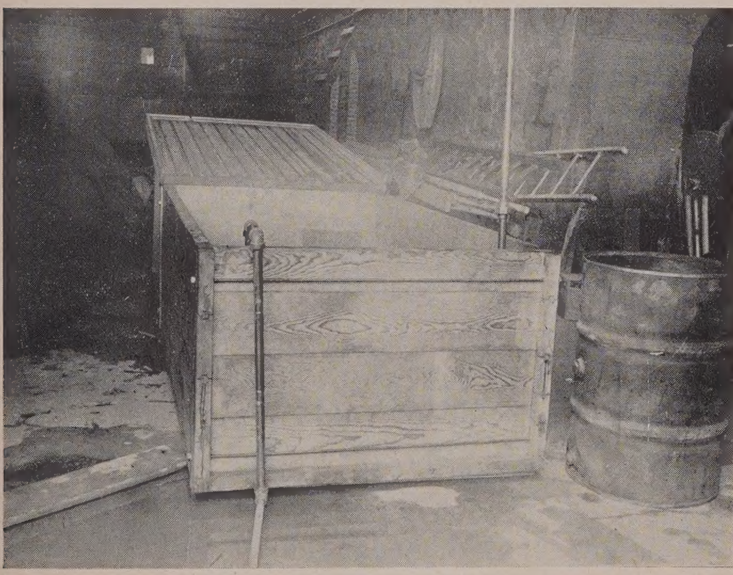

Figure 19.—Method of heating solution when steam is available. The steam passes through submerged coil, under false bottom, heating the formalin solution to desired temperature.

If only a small amount of seed is to be treated, an ordinary cast iron kettle, the type used on the farm in which water is heated to scald hogs, is suitable. The kettle is hung over an open fire. An old galvanized iron wash tub, perforated with many holes, can be used to lift the potatoes in and out of the hot solution.

A homemade dipping tank can be made by using 2-inch planks for the sides. On the bottom a sheet of heavy galvanized iron is nailed in such a manner that it laps over the sides for about 2 inches. Such a tank can be placed over a fire which is confined in a hole in the ground. If made large enough to accommodate 5 to 8 sacks, crosswise, several hundred sacks of potatoes can be treated

in a day. It would be well to place a false bottom in the tank. Ordinary galvanized iron stock tanks can be used in which to heat the solution.

A convenient source of heat is steam, if it is available. The steam is run through a submerged coil with an inlet and outlet valve. The coil should be placed in the solution below a false bottom. This latter prevents the potatoes from contacting the hot coil. An outlet valve is desirable in order to manipulate the steam pressure in the coil, thus more readily controlling the temperature of the solution. When steam is available, this method lends itself very nicely to a community basis of treating the seed potatoes.

Mercury

Long-time cold method. This chemical is available in two types of compounds—namely, as mercuric chloride (corrosive sublimate) and as an organic compound (New Improved Semesan Bel). Mercuric chloride it is generally used in solution at ordinary temperatures, made by dissolving 4 ounces of the material in 2 quarts of hot water, then made up to 30 gallons. The potatoes are dipped in this solution for 1½ hours. Only wood, enamel ware, or concrete containers should be used, since this chemical reacts rapidly in contact with other metals, thus weakening the solution. The chemical also reacts rapidly with organic matter such as dirt on the tubers and burlap, which likewise weakens the solution. It is a known fact that the solution weakens with use to such an extent that the chemical should be added at the rate of ½ ounce for every 5 bushels of potatoes treated. Following 6 to 8 dippings, the solution should be discarded and a new one made up.

This method has several undesirable features. *Mercuric chloride is a deadly poison* when taken internally. Precautions should be taken in the disposal of the old solutions and in the disposal of those treated tubers in excess of the number needed for seed. *Do not feed to stock.* Vats containing the solution should be carefully covered when not in use. Like the cold formalin method, the cold mercuric chloride method has the disadvantage of the time element involved.

Acid-mercury dip. In order to eliminate the time element, one disadvantage of the long-time mercuric chloride method, a short-time dip treatment using the same material has been instituted. It is known as the acid-mercury dip. In this method the mercury salt is dissolved in hydrochloric acid (muriatic acid) and then made up to volume with water. Six ounces of mercuric chloride are dissolved in 1 quart of commercial hydrochloric acid. It will dissolve in a few seconds. This solution is then added to 25 gallons of water in a nonmetallic container. The seed tubers are then dipped in this solution for 5 minutes. If tubers are not planted immediately, they should be dried, particularly so if they are to be returned to storage.

This method possesses some of the bad features concomitant with the long-time mercuric chloride method. There is still the poisonous feature involved. After several dippings the solution must

be renewed, since the mercury is taken out of solution by contact with organaic matter and metals.

The acid solution of mercuric chloride can be obtained in the market under the trade name "Mercurnol." One quart of this solution is added to 25 gallons of water, and the material is ready to use.

Organic mercury. This material can be purchased on the market under the name of New Improved Semesan Bel. It is used as a solution in the proportion of 1 part of the material to 60 parts of water (1 pound to 7½ gallons of water). The uncut seed is momentarily dipped into the solution and then removed and dried. If only small amounts of seed are to be treated, a couple of 3- or 4-gallon pails can be used. The potatoes are placed in one pail, and the material is poured over them. The excess material in pail No. 1 is then poured over potatoes contained in pail No. 2. For large quantities of seed, a vat and drain board can be rigged up. The potatoes can be placed in the solution by means of conveniently sized crates or baskets, or by means of an automatic conveyor. This material and the convenient method of its application have become quite popular. A rapid and efficient method of treatment results from its use.

General Considerations on Seed Treatment

Seed treatment is not a cure-all for diseases of potatoes. It will control the surface-borne pathogens which cause rhizoctonia, common scab, blackleg, and dry rots.

It is best to treat whole potatoes, although cut seed may be treated with New Improved Semesan Bel to very good advantage.

With the exception of tubers treated with Semesan Bel, all treated tubers should be thoroughly dried, particularly if they are to be replaced in storage. Failure to dry them before replacing in storage may result in poor stands.

Plan the date of treatment so that it will precede the date of planting by at least 10 days or 2 weeks. This will permit the potatoes to recover from shock incident to treatment.

Care should always be taken in using any of the mercury compounds. They are poisonous when taken internally.

Storage

Considerable loss is incurred on the part of the growers due to various rot-producing organisms attacking the tubers during the storage period. Much of this trouble can be overcome if sound potatoes are placed in a well-ventilated storage held around 40° F., which has previously been thoroughly sprayed with a solution of either copper sulphate or formalin. Formulae: 1 pound copper sulphate—10 gallons water; or 1 pint commercial formalin—10 gallons water.